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Improved Performance in Master Runners Competing in the European Championships between 1978 and 2014

Performance trends in master runners grouped by age

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Abstract

The performance trends in elite runners have been well investigated, but we have no knowledge about performance trends and the difference between the sexes in elderly runners competing at a high level in varying distances. The purpose of this study was to investigate the performance of these age groups. Data from seventeen European Championships held between 1978 and 2014 were analyzed for various race distances (i.e. 100 m, 200 m, 400 m, 800 m, 1500 m, 5000 m, 10,000 m and marathon). Running speed for the top 8 female and male finalists for each age group (35-99 years, split into 5 year gaps) and each race distance were included. A two-way analysis of variance compared the effects of sex, race distance, age group and calendar year on speed. Subsequent comparisons between race distances, age groups or calendar years were carried out using a post-hoc Bonferroni test. Our analysis shows that men were faster than women in all distances and the difference between the sexes was greater in the shorter distances. Speed was higher for shorter distances than for longer distances. Younger participants were faster than older ones, and the effect of age group was the largest for the 200 m. There was a minor effect of calendar year on speed in the 100 m, 200 m, 1500 m, 10,000 m and marathon, and a minor calendar year×sex interaction on running speed was shown for the 200 m. For athletes and coaches, the current study demonstrates that both male and female athletes improved their running performance over time and that the sex gap may have reached its limit.

Key words: speed; runner; sex difference; age group athlete

INTRODUCTION

Track and road running is an increasingly popular sports discipline, where participants aim to cover a given distance – usually from 100 m to marathon – as fast as possible (62). The last few years have seen an increase in participation, especially in marathon road running (21, 37). Despite the growing participation in running events of varying distances, little is known about the performance trends of elderly female and male elite athletes in track running (49).

Running speed has improved considerably for both women and men during the last 150 years (62). World records in all running events have been continually beaten over the past century (41). Several factors might contribute to the dramatic increase in running performance. In the late 1970s sports physiology began to be applied to sports training strategies. Different training methods were incorporated, including circuit training, interval training and sprints. A better understanding of various training components probably played a major role in the increase of performance in the last decades (59). Incorporation of an interval training session has been proven to increase running speed on longer runs and lengthen the time to exhaustion in trained athletes (32). During the last century, studies started to include research about resistance training. The first studies about resistance training started in the 1980s. Since then it has been shown that resistance training has an impact on neural mechanisms, metabolic adaptations, the cardiovascular system, the endocrine system, connective tissue and the immune system (33). Changes in training strategies such as an increased training volume helped achieve this progress (52). A greater interest in sport psychology might have helped understanding an athlete’s psychological needs in order to perform better (34). Keegan et al. studied the impact of coaches, parents and peers on an athlete’s motivation and showed that the behaviour of the people in an athlete's environment has a direct, but complex impact on his or her motivation (25). Coaching strategies have changed over time and provide athletes with better techniques for coping with anxiety, which can negatively affect athletic performance (44).

Progress in the medical field might also play a role as it provides more concise medical advice in terms of prevention and therapy of sport injuries (59). For example, research about overtraining syndrome in athletes helps understand the aetiology of this condition and how to avoid and treat it (6). Radiographic imaging, arthroscopy and new surgical methods help provide a better, more complete medical support and play a major role in the increase of performance (59). Another contributing factor might be found in the better understanding of the nutritional demands of an athlete's body (59) and of the hydration needed during endurance performance (26). Advances in health technology including the development of functional magnetic resonance imaging have helped understand brain activity during sports (19).

In the last decades, considerable advances have also been made in the field of sports equipment. We now have access to improved design and quality of shoes, clothing and training equipment. These improvements also helped athletes achieve an increase in sports performance (59). Unfortunately, doping probably also plays a major role in the increase of athletic performance in the last few decades (41). All of these factors and more could play a role in the overall increase of athletic performance.

Men run faster than women. There are several reasons for this difference in endurance performance between the sexes, including higher VO_2max, lower body fat percentage (55), larger hearts, higher haemoglobin levels and greater muscle mass in men (4). Endocrine differences are not to be neglected. Androgens levels are higher in men, and contribute to their higher muscle mass (51), which has an impact on neuromuscular performance (12). Although both men and women have improved their running performance, the relative improvement in running performance observed over the last century was greater in female than in male athletes (41). Some findings even suggested that women would outrun men at some point in the future (64, 65).

The hypothesis of the narrowing difference between the sexes in running performance has been analysed by other authors (8, 21, 54, 68). For instance, Zingg et al. (69) showed that female athletes over 35 years reduced the difference in mountain and city marathons within a decade. In 1922, the difference was about 30% and decreased over time, reaching a plateau at 10.7% in 1984, according to Thibault et al. (58). Other authors state a similar percentage (15, 21). Interestingly, one study shows that the difference between the sexes is smaller in ultra-marathon running, ranging from 0.2-10% (31). The discussion of whether women will catch up to men or whether the difference might be fixed is still ongoing.

Elderly athletes represent a highly active and healthy population with a good quality of life (67). Thus, studies of performance of this athletic elderly population might help to understand the decline in general health with increasing age (67). Aging is generally associated with a decline in both health (40, 67) and endurance performance (56). Over the last few decades, however, greater numbers of elderly people have participated in endurance races (23, 42, 56). In running, elderly athletes have significantly improved their performance between 1975 and 2013 (2).

Regular endurance training, including running, has many health benefits. Several studies demonstrated the benefits of physical activity later in life such as lower overall mortality (18, 63) Lee et al. analysed the mortality risk of over 13,000 runners and found out that runners have a lower mortality risk than non-runners (36). It has been shown that regular exercise reduces the incidence of cardiovascular and respiratory diseases (46). Couppé et al. found that elderly men who had been practicing endurance running for a long time had lower triglyceride and LDL-cholesterol than untrained elderly men. The same group analysed accumulation of advanced glycation end products in the connective tissue and showed that elderly elite athletes have a lower AGE accumulation and higher MRI signal intensity of the patellar tendon, suggesting that endurance training could reduce the age-related deterioration of soft tissues (11). Regular physical exercise has also been shown to improve cognitive function (57).

Based on existing reports describing other disciplines like swimming (27) where improvement over time was shown for elderly swimmers in all age groups and distances, we might assume similar trends in running; however, we have no knowledge about changes in performance trends in age group track runners competing at an elite level in various distances. Such knowledge would be of great value from a theoretical and practical perspective. Sports scientists, especially exercise physiologists, focusing on sex differences would benefit from such knowledge, because they would improve their understanding of the evolution of the differences between males and females in sport performance. On the other hand, coaches and fitness trainers working with age group runners might use such information on sex differences to optimize the training of their athletes.

The possibility of a sub-2-hour marathon has been discussed vividly lately. Though runners are getting faster over time, Tucker et al. do not believe in an imminent sub 2-hour marathon because the current average difference between the sexes is about 11.2% and the achievement of a sub 2-hour marathon would represent a 12.9%

difference. Another point they bring forward is that the 2.4% required improvement in men's performance is unlikely to happen quickly, but rather will take generations to achieve (60). Hoogkamer et al. do believe a sub 2-hour marathon is achievable and drew a draft of how a lighter shoe, a downhill route and tailwind might someday reduce the metabolic cost enough in order to achieve the average velocity of 5.86 m/s required for a sub 2-hour marathon (20).

The first aim of this study was to analyse the performance trends in elite master runners from 1978 until 2014 for 5-year age group intervals from 35 to 99 years for different race distances (i.e. 100 m, 200 m, 400 m, 800 m, 1500 m, 5000 m, 10,000 m and marathon). The second aim was to analyse the difference between men's and women's running performance. We hypothesized that between 1978 and 2014 both men and women improved their running speed and that the difference between the sexes decreased.

METHODS

Experimental Approach to the Problem

In order to investigate the changes of performance (i.e. running speed) of master athletes across the years along with the difference in performance between men and women, we analysed the running speed of men and women for different distances. Data from 17 European Championships held between 1978 and 2014 were analyzed for different race distances (i.e. 100 m, 200 m, 400 m, 800 m, 1500 m, 5000 m, 10,000 m and marathon). Only outdoor track races and marathons held on roads were included due to the different events (e.g. 100 m versus 60 m) and conditions (e.g. 400 m in one lap versus 400 m in two laps) in outdoor and indoor races, respectively. The youngest athletes in the data set were 35 years old. Reaburn and Dascombe (49) defined master athletes as participants of 35 years or older. We therefore considered athletes over 35 years of age to be master athletes and did not include any younger athletes in our study.

Subjects

The European Veterans Athletic Association (EVAA) was founded in 1978 in Italy with the aim to organize European Championships for master athletes and to keep a complete register of the results (http://european-masters-athletics.org/about-us/history.html). We aimed to investigate the results of the European Championships held between 1978 and 2014. The section www.evaa.ch/results.html records the publicly available race results for the years 2000-2014. The result charts for races held between 1978 and 2000 were not available on the website, thus, Ove Edlund, Sweden, provided us with the printed versions for this time period. Both the online and the printed race records included results for the distances 100 m, 200 m, 400 m, 800 m, 1500 m, 5000 m, 10,000 m and the marathon. Each athlete was recorded for distance, race time, nationality and age group. Not every Championships result chart included the competitor's exact age, however, every Championships used the same age groups where athletes were divided into 5-year age group intervals as follows: 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, and 95-99 years. To our knowledge no subject was excluded from the EVAA data set because of the use of doping. This study was approved by the Institutional Review Board of Kanton St. Gallen, Switzerland, with a waiver of the requirement for informed consent of the participants as the study involved the analysis of publicly available data (01/06/2010).

Procedures

We analysed the running performance for athletes between 35 and 99 in 5-year age intervals. The race distances included were 100 m, 200 m, 400 m, 800 m, 1500 m, 5000 m, 10,000 m and marathon. Finally, 14,685 race times (6,019 female and 8,666 male times) were included into the data set. The data set is visible in Table 1. For better comparison, we restricted our analysis to the top eight male and female finishers, as there were different numbers of finishers in each category. Finishers without a recorded race time or who were disqualified for any reason were excluded from our analysis. Running speed was used to compare the performance. As the race times and the distances but not the running speed were listed in the result charts, running speed was calculated in km/h using the equation running speed (km/h) = race distance (m)/race time (sec) × 3.6.

Statistical Analyses

The statistical software IBM SPSS v.23.0 (SPSS, Chicago, USA) performed all statistical analyses. Mean values and standard deviation (s) were calculated for all variables. A two-way analysis of variance (ANOVA) compared effects of sex, race distance, age group and calendar year on running speed. Subsequent comparisons among race distances, age groups and calendar years were carried out using post-hoc Bonferroni test. The magnitude of these differences was examined using effect size eta squared (η^2) and evaluated as: minor ($0.010<\eta^2\leq0.059$), moderate ($0.059<\eta^2\leq0.138$) and major ($\eta^2>0.138$) (9). We analysed the relationship between speed and race duration using a logarithmic regression model. In addition, we examined the differences in the running speed of men and women using the formula

100×(men's running speed–women's running speed)/women's running speed. We also compared variations in running speed by participants' sex, age group, race distance and calendar year by a mixed-effects regression model. In this model, participants were assigned as random variables, whereas sex, age group, race distance and calendar year were assigned as fixed variables. We examined interaction effects among these fixed variables. Akaike information criterion (AIC) was used to select the final model. These analyses were performed for each race distance separately. A regression analysis of cubic degree was performed between running speed and calendar year, and the coefficient of determination (R^2) was calculated. Statistical significance was set at alpha = 0.05.

RESULTS

Performance by sex and race distance

According to the two-way ANOVA, a moderate effect of sex on running speed was observed ($p < 0.001$, $\eta^2 = 0.115$), where men were faster than women, as shown in Figure 1. Also, a major effect of race distance on running speed was shown ($p < 0.001$, $\eta^2 = 0.649$), where short distances were faster than longer ones. In addition, a sex×race distance interaction on running speed was noticed ($p < 0.001$, $\eta^2 = 0.006$) for all distances with the sex difference being greater in the shorter distances. These findings were in agreement with the mixed-effects regression analysis and are shown in Table 2. Figure 2 presents the relationship between running speed and race duration.

Performance by sex and age group

A major effect of sex on running speed ($p < 0.001$), where men were faster than women, was observed for all distances with η^2 ranging from 0.197 (1000 m) to 0.472 (200 m). Figure 3 represents the difference between the sexes for each distance and each age group. In addition, a major effect of age group on running speed ($p < 0.001$), where the younger groups were faster than the older, was shown for all distances with η^2 ranging from 0.474 (marathon) to 0.823 (200 m). A minor sex×age group interaction on running speed ($p < 0.001$), where difference between the sexes was greater in the younger age groups, was noticed for all distances with η^2 ranging from 0.019 (1500 m) to 0.048 (100 m). The findings of the mixed-effects regression analysis were shown in Table 3.

Performance by sex between 1978 and 2014

A minor effect of calendar year on running speed was observed in 100 m, 200 m, 1500 m, 10,000 m and marathon ($p \leq 0.044$, $0.014 \leq \eta^2 \leq 0.050$), but not in 400 m, 800 m and 5000 m ($p \geq 0.160$, $\eta^2 \leq 0.011$) (Figure 4). A small calendar year×sex interaction on running speed ($p = 0.038$, $\eta^2 = 0.013$) was shown for 200 m, but not for the rest of the distances. The findings of the mixed-effects regression analysis were presented in Table 3. The regression analysis of cubic degree between sex difference and calendar year showed variation by race distance: 100 m ($R^2 = 0.41$), 200 m ($R^2 =$ 0 .34), 400 m ($R^2 = 0.628$), 800 m ($R^2 = 0.309$), 1500 m ($R^2 = 0.209$), 5000 m ($R^2 =$ 0.328), 10,000 m ($R^2 = 0.489$) and marathon ($R^2 = 0.046$). These findings are shown in Table 4 and Figure 5.

DISCUSSION

The main findings of the present study were that (i) men were faster than women in all distances, (ii) the difference between men and women in running speed was greater in the shorter distances, with the greatest difference in 200 m and the smallest in 10,000 m, (iii) running speed was faster for shorter distances than for longer distances, (iv) younger participants were faster than older ones, (v) with the effect of age group the largest in 200 m and the smallest for the marathon, (vi) there was a minor effect of calendar year on running speed in 100 m, 200 m, 1500 m, 10,000 m and marathon, and (vii) a minor calendar year×sex interaction in running speed was shown for 200 m.

Men were faster than women for all distances and age groups

The first result was that men were faster than women for all distances and age groups, which was supported by other studies (21, 54). Generally speaking, the difference of 10-12 % between male and female running speeds has been consistent for both shorter and longer distances (16).

Although one might argue that this result was trivial, recent studies investigating master pool swimmers in freestyle (27), breaststroke (29), backstroke (61) and open-water swimmers (28) showed that men were faster than women for younger age groups, but not for older age groups where women achieved a similar performance to men. The explanation was that in the studies with swimmers at the World Championships, no selection by age group occurred and all swimmers in all age groups were considered. The men-to-women ratio changed across age groups and, therefore, explains the fact that women were able to achieve a similar performance to men in the older age groups.

Men were faster than women in our study. This may be due to their lower body fat percentage and their higher VO_2max (55) compared to women. However, these hypotheses were limited, as we did not perform any determinations of body fat or VO_2max. Men also seem to be more competitive (13) and more willing to commit to a high intensity training program (16) than women. There might also be a historical component as it is known that women have been participating in official races for a shorter period of time and have therefore less experience in running races (21). We did not collect any historical data ourselves, but it is known that the first modern Olympic Games were introduced in 1896 with only male athletes, and a century later (in 1984), female runners were first included for the marathon distance (59).

There are other differences between male and female runners. Women tend to have a more even pace throughout a race, while men slow down for the second half of the marathon (14). This difference might be due to different choices while racing or to the fact that men are depleting their muscle glycogen more rapidly than women (14).

In the present study we used running as a way to compare male and female performance and the changes over time. Distance running is a suitable discipline to compare male and female performance because it is objective, open to everyone who wants to participate and popular among men and women (13). Sex differences in endurance performance were also found in other athletic disciplines. In swimming races, the sex differences seem more important in elderly than in younger swimmers, though not as important as in marathon running (53).

The difference between the sexes was greater in shorter race distances

A second important discovery was that the difference in male and female running speed was greater for shorter distances and smaller for longer distances. The effect of sex was the highest for the 200 m distance and the smallest for the 10,000 m distance. Sprint performance depends on peak power output, which increases linearly with the amount of lean mass in the lower extremities, and is higher in males (43). Proportionally, women oxidize more fat than men during endurance exercise (7), which might help explain why women are less fatigued on longer distances (8). Other contributing factors to fatigue could be hormonal differences as oestrogens are known to have a protective role in exercise-related muscle damage that accompanies longer aerobic exercise (66).

Running speed was faster for shorter distances

Another discovery was that running speed was faster for shorter distances than for longer ones. This result was expected and has been demonstrated by other authors. For example, Weiss et al. (62) showed that running speed decreased with increasing race distance. Different physiological factors cause a reduction of physical effort including cardiorespiratory capacity, VO_2max and muscle fatigue (24).

Younger athletes were faster than elderly athletes

Another important result was that younger competitors ran faster than elderly athletes for every distance. This effect of age on running speed was expected and has been demonstrated by other authors (10, 21, 30, 56).

The best running times are often achieved by the age of 35 years with a small and linear decline until about 50-60 years of age, with a more pronounced decline after that (56). A decline in VO_2 which is due to a reduction in cardiac output, an increase in body fat percentage, a reduction in peripheral oxygen extraction and most importantly, a reduction in muscle mass (48), seems to play an important role in the decline of running performance in elderly athletes (47). Younger master athletes have higher muscle mass and a greater number of motor units than older master athletes (17). Muscle atrophy causes a reduction of muscle mass (1, 3). Muscle atrophy in turn could partially be explained by neuronal dysfunction (5). Therefore, the age-related muscle loss contributes to the reduction of VO_2max (48) which in turn plays an important role in the age-related decrease of running speed (47).

The oldest competitors in our study were 97 years old, but other authors reported great sports performance of centenarians (38), showing that physical activity is possible until late in life. Age-related sarcopenia could also play a role in the performance decline. Sarcopenia is defined by a decrease in number and function of muscle fibres. It is the result of various factors including age-related defect in autophagy resulting in protein accumulation, impaired mitochondrial function due to increased reactive oxygen species, diminished regenerative potential of muscle fibres, degenerative atrophy, vitamin deficiencies and hormonal changes. Muscle mass and strength are also linked to testosterone levels. An increase in age correlates to decreased testosterone levels in both men and women, which is linked to a decrease in muscle mass, particularly in men (45)

The effect of age group was greatest for 200 m and smallest for the marathon

Another finding was that the age-associated decline in performance was the largest for the 200 m distance and the smallest for the marathon. There are divergent results in current literature. Rittweger et al. showed that the age-related decrease in running performance was similar for both sprint and long-distance runners (50). Drey et al. (17) compared the skeletal muscle mass in power- and endurance-trained master athletes competing in the 2012 European Championship held in Zittau, Germany. Power-trained master athletes had a better muscle mass than endurance-trained master athletes (17). During the aging process relatively more type II muscle fibres are lost (39). This could explain why in our study, the age-related decline was more pronounced for the 200 m distance and smallest for the marathon. Both sprinting and long-distance training are beneficial during the aging process (35). The fact that 99-year old athletes were competing in Championships shows that aging might come with a decrease in running performance but it is compatible with an active lifestyle.

Effect of calendar year on speed in 100 m, 200 m, 1500 m, 10,000 m and marathon

Another important discovery was an effect of calendar year on running speed for most distances. It has been suggested by different authors that running performance has been improving over the years (56, 62). World records in athletic sports like running have dramatically increased over the past century. The improvements in race times were directly proportional to race distances, meaning the smallest improvements were achieved on short distances like 100 m and the largest improvements were observed in longer distances such as marathon running (41). Weiss et al. showed that the improvement observed at the beginning of the century is now stagnating (62).

Small calendar year×sex interaction on speed for 200 m

The last significant finding was that the difference between the sexes has decreased over the years, but only for the 200 m distance. We expected that the difference would be decreasing for every distance; however, results of earlier studies were divergent. Thibault et al. (58) showed that the difference has been stable since 1984 and that the gap will most likely not be closed. Hunter et al. (22) show that the difference diminished between 1980 and 2010. The researchers also claimed that the male-female difference is closely linked to the male-female participation ratio and therefore many studies have a historical and sampling bias (21).

Limitations and strengths

A limitation of these discoveries was that the present study focused on European athletes and outdoor Championships. Thus, caution was needed to generalize these findings to non-European athletes and indoor Championships. Non-Europeans showed superior performance in athletic running events and their performance would be expected to vary differently by calendar year and sex. Moreover, some events differed between outdoor and indoor competitions (e.g. 100 m versus 60m, 5000 m versus 3000m, respectively) or do not exist in indoors competitions (10,000 m and marathon) and those which existed in both competitions (e.g. 400 m) included different numbers of laps (e.g. one versus two) affecting the physiological, technical and tactical demands of a similar distance. Nevertheless, the strength of the study was its novelty as it is the first one in this topic, adding novel information about the variation of performance of master runners by calendar year and sex.

In conclusion, male runners are generally faster than females. The the gap between male and female endurance performance has been decreasing over the past decades but that it seems to have reached a limit. In general, all athletes are getting faster over time.

PRACTICAL APPLICATIONS

For athletes and coaches, information acquired through this study could have practical implications for practitioners working with master runners; most training programs were developed and applied originally in men, and, thus, knowledge about sex differences would help coaches designing tailored training programs for women, as well. In addition to this practical application, the results about the variation of performance by age group and the variation of the effect of age by race distance would be of interest for researchers studying master athletes as a model of effective aging and for sports scientists, especially exercise physiologists, focusing on sex differences in sport performance.

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Table 1 Available data for each race distance at the events considered in our study

			100 m	200 m	400 m	800 m	1500 m	5000 m	1000 m	marathon
1978	Viareggio	men	x	x	x	x	x	x	x	x
		women					x	x		x
1980	Helsinki	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x		x
1982	Strasbourg	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
1984	Brighton	men	x	x	x	x	x	x	x	
		women	x	x	x	x	x	x		
1986	Malmö	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
1990	Budapest	men	x	x	x	x	x	x	x	
		women								
1994	Athen	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
1996	Malmö	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
1998	Cesenatico	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
2000	Jyväskylä	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
2002	Potsdam	men	x	x	x	x	x	x	x	
		women	x	x	x	x	x	x	x	
2004	Aarhus	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
2006	Poznan	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
2008	Ljubljana	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
2010	Nyiregyháza	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
2012	Zittau	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x
2014	Izmir	men	x	x	x	x	x	x	x	x
		women	x	x	x	x	x	x	x	x

Table 2 Coefficients (C) and standard errors of estimate (SEE) from multi-variate regression models for race speed of participants by sex and race distance.

	C	**SEE**	**p**
Sex	-3.18	0.08	<0.001
Race distance	-2.06	0.02	<0.001
Interaction sex×race distance	0.17	0.02	<0.001

Table 3 Coefficients (C) and standard errors of estimate (SEE) from multi-variate regression models for race speed of participants by sex and age group for each race distance.

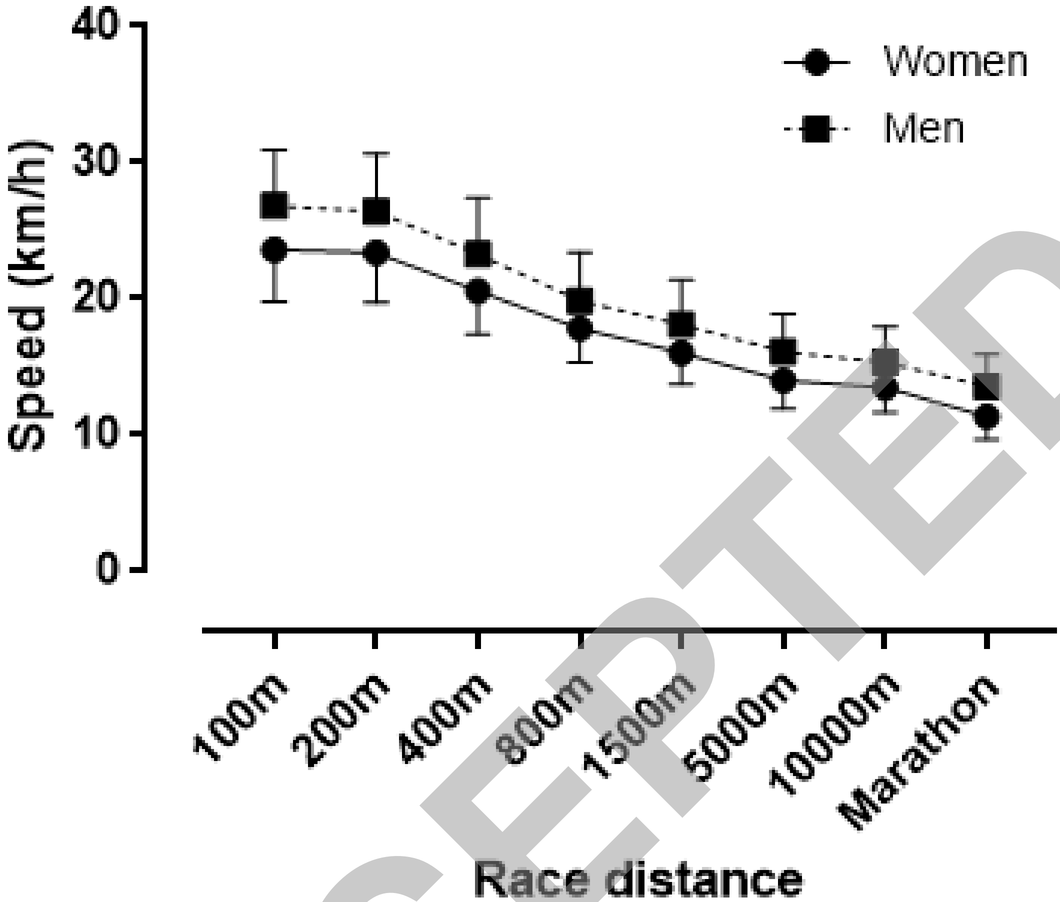
		C	SEE	p
100 m	Sex	-4.06	0.18	<0.001
	Age group	-1.19	0.02	<0.001
	Interaction sex×age group	-0.10	0.03	0.001
200 m	Sex	-4.63	0.17	<0.001
	Age group	-1.29	0.02	<0.001
	Interaction sex×age group	-0.02	0.03	0.481
400 m	Sex	-5.21	0.15	<0.001
	Age group	-1.34	0.02	<0.001
	Interaction sex×age group	0.14	0.03	<0.001
800 m	Sex	-4.85	0.13	<0.001
	Age group	-1.24	0.01	<0.001
	Interaction sex×age group	0.23	0.03	<0.001
1500 m	Sex	-4.37	0.14	<0.001
	Age group	-1.08	0.02	<0.001
	Interaction sex×age group	0.20	0.03	<0.001
5000 m	Sex	-4.16	0.11	<0.001
	Age group	-0.98	0.01	<0.001
	Interaction sex×age group	0.21	0.02	<0.001
1000 m	Sex	-4.13	0.15	<0.001
	Age group	-0.91	0.02	<0.001
	Interaction sex×age group	0.27	0.03	<0.001
Marathon	Sex	-4.51	0.18	<0.001
	Age group	-0.82	0.02	<0.001
	Interaction sex×age group	0.35	0.04	<0.001

Table 4 Coefficients (C) and standard errors of estimate (SEE) from multi-variate regression models for race speed of participants by sex and calendar year for each race distance.

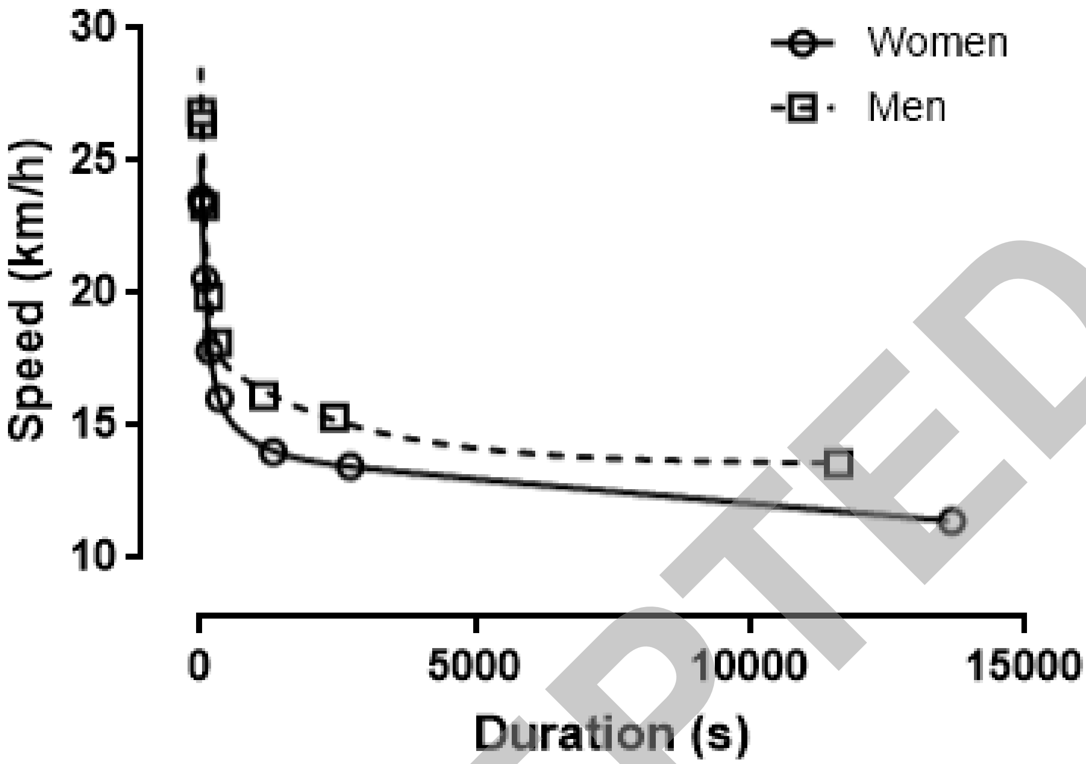
		C	SEE	p
	Sex	-0.87	33.20	0.979
100 m	Calendar year	0	0.01	0.948
	Interaction sex×calendar year	0	0.02	0.944
	Sex	-58.47	35.01	0.095
200 m	Calendar year	-0.02	0.01	0.161
	Interaction sex×calendar year	0.03	0.02	0.113
	Sex	6.67	34.19	0.845
400 m	Calendar year	-0.01	0.01	0.636
	Interaction sex×calendar year	0	0.02	0.783
	Sex	25.81	29.66	0.384
800 m	Calendar year	-0.01	0.01	0.219
	Interaction sex×calendar year	-0.01	0.01	0.348
	Sex	4.77	24.40	0.845
1500 m	Calendar year	-0.02	0.01	0.003
	Interaction sex×calendar year	0	0.01	0.779
	Sex	-13.03	20.69	0.529
5000 m	Calendar year	-0.02	0.01	0.010
	Interaction sex×calendar year	0.01	0.01	0.596
	Sex	39.86	35.34	0.260
1000 m	Calendar year	-0.02	0.01	0.017
	Interaction sex×calendar year	-0.02	0.02	0.239
	Sex	-3.69	22.42	0.869
Marathon	Calendar year	-0.02	0.01	0.002
	Interaction sex×calendar year	0	0.01	0.946

List of figures

Figure 1


Speed (km/h)
0
10
20
30
40
Women
Men
100m
200m
400m
800m
1500m
5000m
10000m
Marathon
Race distance

643 **Figure 2**



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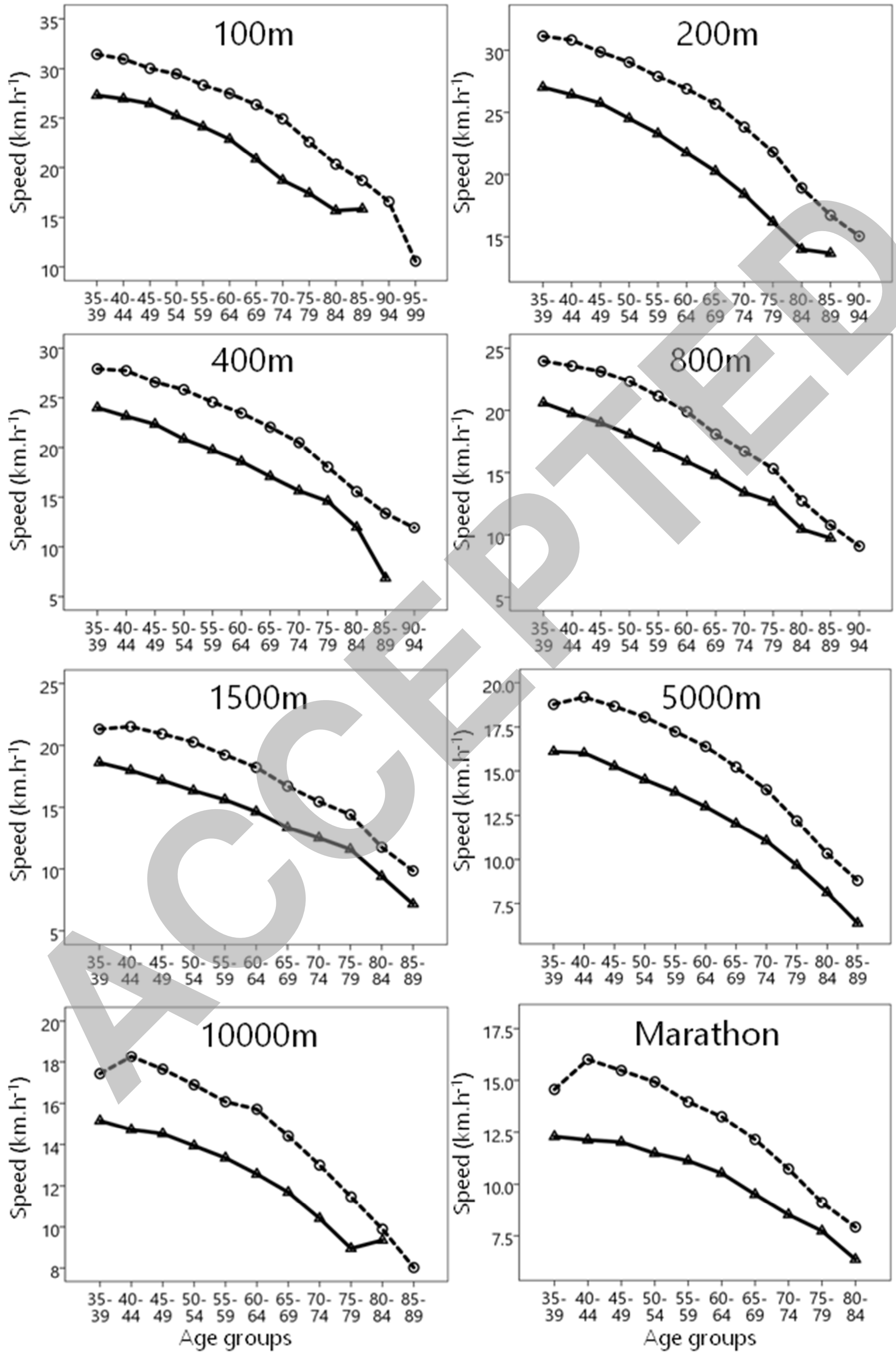

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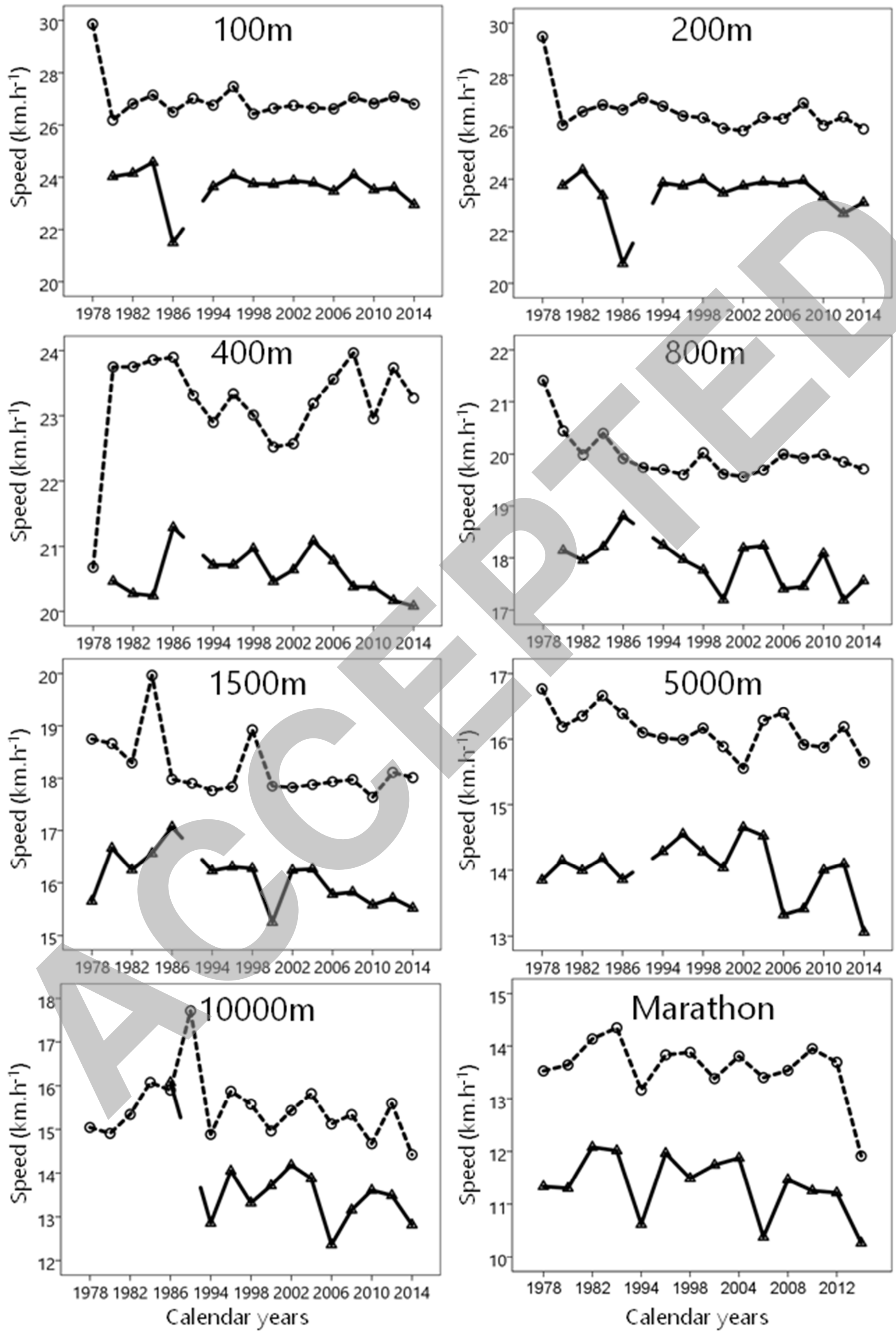

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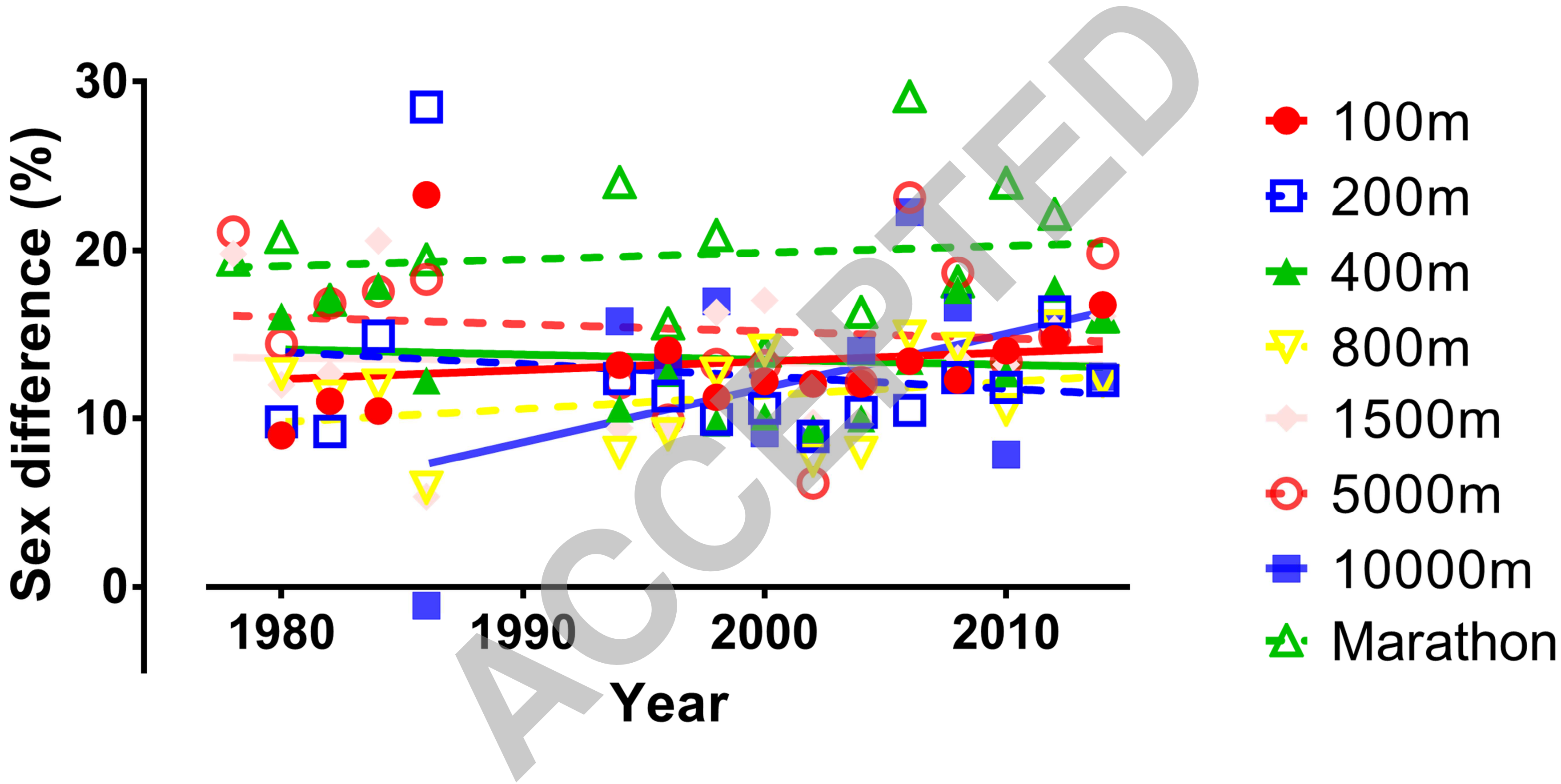
651 **Figure 5**



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